SEASONAL OCCURRENCE AND ECOLOGY OF SALT MARSH PHANEROGAMS AT IPSWICH, MASSACHUSETTS[1]

E. E. WEBBER

For the past several years, research into the ecology and systematics of benthic algae has been in progress at a salt marsh adjacent to the Castle Neck River, Ipswich, Massachusetts. Because of the close association between many of these algae and the salt marsh seed plants, it was essential to characterize this salt marsh area as to its phanerogam vegetation. The present paper reports on the presence and distribution of the dominant seed plants characteristic of the Ipswich salt marsh.

Principal references used for species determinations were Gleason and Cronquist (1936), Mason (1957), and Fernald (1950). Specimens of the plants collected are deposited in the Herbarium, University of Massachusetts, Amherst.

The phanerogams collected as indicative of the Ipswich salt marsh and its immediate surroundings are as follows:

MONOCOTYLEDONAE

Ruppia maritima L.
Triglochin maritima L.
Eleocharis halophila Fern. & Brack.
Scirpus americanus Pers.
Juncus gerardi Loisel.
Bromus tectorum L.
Glyceria melicaria (Michx.) Hubb.
Distichlis spicata L.
Phragmites communis Trin.
Agropyron pungens (Pers.) R. & S.
Spartina pectinata Link
Spartina alterniflora var. *glabra* (Muhl.) Fern.
Spartina patens (Ait.) Muhl.
Panicum virgatum L.

[1]Modified from a section of a Ph.D. thesis, "Systematics and Ecology of Benthic Salt Marsh Algae at Ipswich, Massachusetts", submitted to the Gradi ate Faculty, University of Massachusetts, Amherst.

DICOTYLEDONAE

Myrica pensylvanica Loisel.
Polygonum aviculare L. var. *littorale* (Link) Koch
Bassia hirsuta (L.) Aschers.
Atriplex patula var. *hastata* (L.) Gray
Salicornia bigelovii Torr.
Salicornia europaea L.
Suaeda maritima (L.) Dum.
Suaeda richii Fern.
Suaeda linearis (Ell.) Moq.
Spergularia marina (L.) Griseb.
Trifolium arvense L.
Hudsonia tomentosa Nutt.
Glaux maritima L.
Limonium nashii Small
Gerardia maritima Raf.
Plantago maritima L.
Solidago sempervirens L.
Aster sp.

SEASONAL DEVELOPMENT.

Two of the dominant species, *Juncus gerardi* and *Spartina patens,* began their growth period far earlier than the remainder of the marsh phanerogams. Young green shoots of these two species a few centimeters in height were collected from beneath the ice and snow covering the marsh in February, 1963 and 1964. By early May *Juncus gerardi* shoots had increased to 15 cm in height, while those of *Spartina patens* were 7 cm tall.

In contrast, emergent shoots (1-3 cm tall) of the following plants became apparent in early May throughout the marsh:

Glaux maritima
Eleocharis halophila
Plantago maritima
Atriplex patula var. *hastata*
Suaeda richii
Suaeda linearis
Limonium nashii

The first flowering of salt marsh phanerogams began in late May with *Glaux maritima, Eleocharis halopila,* and *Plantago maritima.* These were followed in June by *Juncus gerardi, Scripus americanus, Phragmites communis,* and *Ruppia maritima.* By July, *Spartina patens* and *Limonium nashii* joined the species already in bloom. The majority of seed plants flowered during August, among them the following:

Suaeda linearis	*Salicornia bigelovii*
Suaeda richii	*Salicornia europaea*
Spergularia marina	*Bassia hirsuta*

In September, the marsh appearance changed from a lush summer green to an autumn brown with splotches of yellow, purple, and red belonging to the blooms of *Solidago sempervirens*, *Aster sp.*, and the stems of *Salicornia sp.* respectively. Also in flower during September, but much less evident than the aforementioned autumn species, was *Gerardia maritima*, growing among the taller culmns of *Spartina patens* and the scapes of *Plantago maritima*.

DISCUSSION OF PHANEROGAM DISTRIBUTION.

Throughout the Ipswich marsh the phanerogam vegetation follows a recognizable pattern of distribution. In a landward direction the dominant species succeed each other in the following sequence: *Spartina alterniflora* var. *glabra*; *Spartina patens*; a mixture of *Spartina patens* and *Distichlis spicata* or, where the topography was sloping, a *Spartina patens — Scirpus americanus* mixture; and *Juncus gerardi*.

Historically, explanations of seed plant distribution in the salt marsh habitat have emphasized the importance of tide levels in conjunction with the ability of a particular species to tolerate varying concentrations of salt in the soil solution, as well as periods of tidal immersion.

Johnson & York (1915) related tide levels on Long Island marshes to seed plant zonation, and suggest that the upper and lower distributional limits for a particular plant are controlled by the ability of that plant to withstand specific periods of submergence and emergence. These authors also indicate that light availability may be involved in the maximum downshore extension of *S. alterniflora* var. *glabra*, a point recently reemphasized by Ranwell, et al. (1964).

On the Saugus marsh (Massachusetts), Chapman (1940) found the tidal factor to be ultimately the most important ecological variable in controlling phanerogam distribution.

Additional investigations of phanerogam distribution on other North American salt marshes indicate the importance of tide levels as they influence soil salinities and soil drainage (Penfound & Hathaway, 1939; Uphof, 1941; Purer, 1942; Reed, 1947; Hinde, 1954).

Results of culture experiments reported to date suggest that, in general, different salinity tolerance levels (Taylor, 1939) and specific nutrient requirements (Adams, 1963) of the various species are responsible for their zonation in salt marshes. An excellent review of pertinent physiological data attempting to explain, at least in part, the distribution of salt marsh seed plants has been presented by Chapman (1960).

At the Ipswich marsh I have recognized the importance of several factors related to phanerogam distribution, e.g., proximity to saline or fresh water influences, marsh surface topography, and character of the substrate.

The pioneer phanerogam to colonize the marsh was *Spartina alterniflora* var. *glabra,* forming a band of vegetation along marsh edges and creek margins. Its landward extent coincides with high water neap tide levels. Maximum vegetative and reproductive growth was restricted to those plants on the marsh near this level. At its lower limit, this species was only several centimeters tall and typically vegetative. The distribution of *S. alterniflora* var. *glabra* at Ipswich is confined to marsh areas with muddy substrate, poor drainage, repeated tidal inundation, and continual mud and silt deposition.

Above high water neap tide levels an extensive *Spartina patens - Distichlis spicata* mixture occurred on flat sections of the marsh which lacked even the slightest slope. In Connecticut, Nichols (1920) found that poorly drained marsh areas above high water neap tide levels were populated by *Distichlis spicata,* and with improved soil drainage *S. patens* became abundant. Taylor (1939) noted that *D. spicata* was more vigorous in growth and flowering at higher salinities in culture solutions. While Purer (1942) has reported *D. spicata* to be typical of marsh sections having reduced salinities and improved aeration, Adams (1963) using nutrient solution experiments, has shown that *Distichlis* grows best in a saline medium. It may be that the flat and more fully exposed marsh areas at Ipswich had a higher soil salinity than sloping, better drained situations, thereby accounting for the characteristic distribution of *Distichlis spicata.*

The presence of a zone lacking vegetation, a "barren zone", was evident immediately landward to the *Juncus gerardi* consocies on the marsh adjacent to the Castle Neck River. The gently sloping character of the marsh here permitted the retention of tidal debris in this "barren zone". In their study of Connecticut tidal marshes, Miller and Egler (1950) noted that tidal trash in the upper *Juncus gerardi* consocies commonly killed the plants which it covered. At Ipswich the mass of debris, with its accompanying high temperatures and poor air circulation, very likely had a similar effect on a potential vegetation becoming established in this zone. Perhaps high temperatures beneath this debris resulted in excessive salinity, both factors acting to prevent the establishment of seedlings.

A tidal creek at the head end of the marsh was the sole habitat for *Ruppia maritima,* where the plants, anchored in the soft mud of the creek bed, undoubtedly aid in stabilizing this substrate. The plants were never exposed during periods of low tides; indeed, *Ruppia* is unable to withstand exposure to the desiccating effects of sun and air (Chapman, 1960). Citations are common indicating the restricted distribution of *R. maritima* to "brackish water" areas, without specifying salinity readings. An early account of the response of *R. maritima* to varying salinities was made by Graves (in Harshburger, 1909) who found cells of *Ruppia* to tolerate salinities to 25°/oo, but to plasmolyze in salinities of 30°/oo. Maximum growth and development of *Ruppia maritima* at Ipswich was related to a summer salinity range of 20-25°/oo (once to 27°/oo).

Equally distinctive and more characteristic as a salt marsh phanerogam is the genus *Salicornia*. Its brilliant scarlet autumn coloration together with its clonal distribution on the marsh signify "salt marsh" to the observer. Species of *Salicornia* have long been recognized as true halophytes. Halket (1915) and Taylor (1939) have shown experimentally that this plant grows best in 2-3% NaCl solutions. Numerous additional reports pertaining to the halophytic character of the various species of *Salicornia* are contained in Chapman (1960). For the Bay of Fundy marshes (Ganong, 1903), *S. stricta* is typically one of the first phanerogams to colonize eroded segments of the marsh, and for New England marshes, a Salicornetum characteristically develops on bare mud, where high salinities would be encountered (Chapman, 1960). At Ipswich, *Salicornia bigelovii* was abundant in the more poorly drained sections of the marsh, and where the plants were entirely submerged during high water spring tide levels. In contrast, *Salicornia europaea* was always limited to the better drained areas, e.g., as scattered plants along the lower edge of the Spartinetum patentis. However, in several marsh depressions at the head of the marsh *S. europaea* was often the sole component. While soil salinities were not determined for those marsh areas with *S. bigelovii* and *S. europaea*, the proximity to fresh water influence and the greater retention of rain water in the depressions at the head of the marsh, may have produced a less saline environment more conducive to the development of *S. europaea*.

Seed dissemination and germination for the salt marsh annuals is an area of investigation which has progressed little beyond a general consideration of but a few species. During his study of the Saugus marsh, Chapman (1940) noted that seed germination of the annual species occurred in the spring, when the salinity level of the soil surface layers was low. In laboratory experiments he showed that maximum germination of several species occurred in fresh water, although optimum germination for *Salicornia bigelovii* from Saugus (Massachusetts) required a 1% NaCl solution. He also demonstrated that freezing temperatures interact with salinity levels in affecting seed germination of *S. bigelovii*, for while the per cent germination decreased with increasing salinities, this was partially offset by lower temperatures.

In contrast to *Salicornia*, seeds of *Plantago maritima* germinate best in fresh water (Chapman, 1940). At Ipswich *Plantago maritima* and *Glaux maritima* appeared in early May, their seeds apparently germinating when the salinity of the marsh surface soil would be expected to be lowest.

Another consideration relating to salinity and seed plant growth pertains to changing salinity levels as the plants age. Turner (in Chapman, 1960) has shown that *Suaeda novae-zelandiae* grows best in a 1% NaCl solution during its early stages, but that when the plants are six months old, a 3% NaCl solution yields maximum growth and development. It is clear that while salinity levels are important in the germination of some salt marsh annuals, one must also consider salt concentrations of the soil solution throughout the growing season as the plants develop. The distribution of *Suaeda (maritima, linearis, richii)* at Ipswich occurred in the upper marsh levels, as scattered plants among *Spartina patens* or, occasionally, at the upper boundary of *Juncus gerardi*. Seed germination of *Suaeda maritima* is best in fresh water, although the per cent germination is very small (4%); however, another species, *S. novae-zelandiae*, has an optimum of 41% in fresh water (Chapman, 1960). Germination of *Suaeda* seeds at the higher marsh levels at Ipswich may be related to low soil salinities which probably exist here during the early spring.

Atriplex patula var. *hastata* also occurs with *Suaeda* at these higher marsh levels. Seed germination in *Atriplex* is inhibited by the high chloride content of sheathing bracteoles, for removal of these bracteoles results in immediate germination (Beadle, 1952). At the higher marsh levels, the chloride concentation of *Atriplex* bracteoles could be reduced readily by spring rains, resulting in early spring germination which was observed for this species at Ipswich.

It is immediately evident that continued research is necessary with the salt marsh phanerogams to define their specific growth requirements, and therefore more accurately interpret their distribution in salt marshes. Additional and detailed field studies coupled with laboratory experiments should be initiated with this view in mind.

DEPARTMENT OF BIOLOGY
KEUKA COLLEGE
KEUKA PARK, NEW YORK

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SPOROBOLUS TEXANUS VASEY IN LINCOLN, NEBRASKA

Sporobolus texanus was collected in saline soils in Lincoln, Nebraska on July 7, 1965, *Ungar 1190* (KANU), and August 28, 1967, *Ungar 1231* (Ohio University Herbarium). This is the northeasternmost extension of the range of this species. It is about 70 miles east and 80 miles north of any previously reported collection of *S. texanus.*

Prior to this collection, the most northern and eastern collection had been reported by Gates (1940) for Cloud County, Kansas, which is in northcentral Kansas. According to Hitchcock (1950) *S. texanus* is primarily a southwestern species, occurring in Kansas, Oklahoma, Texas, Colorado, Arizona, and New Mexico. It occurs in non-saline prairie soils, prairie bordering saline marshes, and is occasionally an invader of open salt flats from Oklahoma north to Lincoln, Nebraska (Ungar, 1965, 1966, 1967).

S. texanus occurs in two communities in the Lincoln marsh area on the south side of Highway 6-2, opposite 720